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THE TESTING OF JET ENGINES (CHAPTER 9),(U)
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FOREIGN TECHNOLOGY DIVISION

THE TESTING OF JET ENGINES
(Chapter 9)

by

L. S. Skubachevskiy

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MEASURES FOR SAFETY AND FIRE PREVENTION DURING TESTING OR THERMOJETS AND THEIR UNITS

Chapter 9

Testing stations refer to workshops with dangerous working conditions. The technicians who work at the testing station, if they do not observe the appropriate regulations can be exposed to the effect of a number of harmful factors capable of damaging human health. Therefore, in accordance with the decisions adopted by the Soviet government, a number of preventative measures are taken at the testing stations (fencing off dangerous zones, systematic explanation of the safety and fire prevention rules to the technicians, etc.) which promote a reduction in traumatic injury and preservation of the health of the staff at the testing stations.

Among the different measures directed towards creating safe and harmless working conditions, the most important are:

a) reduction of noise in the working area and surrounding space;

b) prevention of air pollution in the work areas by harmful vapors and gases;

c) correct use of load-lifting mechanisms;

d) protection from debris from blades and disks during motor accidents and special tests;

e) fire prevention.

9.1. Noise Control

Noise control is a very urgent problem. All the testing stations are equipped with special sound-suppressing devices. The walls of the structures in which there is especially high noise intensity should be covered with porous material--porolon or acoustic porous plaster should be used when the walls are being finished.

The efficacy of various means of sound-suppression is affected by correct use.

An increase in temperature and gas velocity results in premature destruction of the porous layer of sound-suppressors. Such a suppressor can no longer reduce noise intensity to the permissible amount.

In the construction of the actual testing units one can also plan several measures to reduce noise. It is known, for example, that thin walls of pipes and air ducts begin to vibrate more quickly, while the vibrating elements of the design are the source of noise. Therefore it is necessary to take this situation into consideration also when selecting the thickness of pipe walls.

9.2. Control of Harmful Vapors

During the testing of VRD thermojets in work areas vapors and gases which are harmful to human health can accumulate, for example, carbon monoxide, vapors of kerosene, gasoline and oils, carbon tetrachloride, dichloroethane, mercury and other substances.

Carbon monoxide can accumulate in the area in cases where complete fuel combustion is not ensured and there is poor ventilation in the structure. Fuel spilled on the floor or non-hermetically sealed pipes can be causes of air contamination with vapors which in a concentration exceeding the permissible sanitary norms elicit chronic diseases of the respiratory organs (irritation of mucuous membranes of throat and nose, gasoline pneumonia).

Carbon tetrachloride used for washing motor parts is toxic in itself. If it comes in contact with fire it breaks down forming toxic gas--phosgene.

Especially dangerous are mercury vapors which result in stomatitis, and in certain cases produce anemia and disorder of the central nervous system. Therefore mercury is used for filling pressure gages and other instruments only in extreme cases, at the same time taking the strictest precautionary measures when using these instruments. Mercury spilled on the floor is carefully removed

with active magnesium dioxide or 20% solution of ferric chloride. Work in the area is only allowed after checking the concentration of the mercury vapors in the air. In case the concentration exceeds the permissible, the area is repaired with the removal of the plaster from the lower wall section, the flooring and the entire construction debris.

The maximum permissible concentrations of harmful substances in the air of work areas are given in table 9.1.

It is necessary also to take protective measures. The pressure gage pipes with mercury are usually enclosed with sheets of plexiglass 5 and 7 (fig. 9.1.). Underneath is placed a pan (tray) 10 with water for collecting mercury in case pipe 6 breaks. Above the ends of pipe 6 are joined to the mercury catches (overflow containers) 2 in case it is knocked out during extremely great pressure. In order to prevent the evaporation of mercury in the pressure gage its surface is flooded with water while the free ends of the pressure gage are united in the collector and its outlet end is removed from the area.

In recent years due to the appearance in use of multiple-point pressure gages of high accuracy it is attempted not to use mercury pressure gages at all.

The primary measures for controlling harmful vapors and gases include the unit of reliable balanced ventilation system. The air intake in the area generally occurs from its lower section since the majority of harmful substances are heavier than air and below their concentration is higher. The necessary frequency of the number of air exchanges per hour depends on the type of structure and fluctuates within:

in observation and control booths	15-20
in measuring rooms	5-10
in gas flushing areas	20-25
in testing rooms	2-3

TABLE 9.1.

MAXIMUM PERMISSIBLE CONCENTRATIONS OF HARMFUL GASES, VAPORS AND DUST IN AIR OF WORK AREAS

Name of Substance	Amount of maximum permissible concentration in mg/m^3
Acetone	200.0
Gasoline	300.0
Kerosene	300.0
Dichloroethane	10.0
Carbon monoxide	20.0
Mercury	0.01
Sulfuric acid	1.0
Ethyl alcohol	1000.0
Hydrogen cyanide and cyanide (in conversion to HCN)	0.3
Carbon tetrachloride	20.0
Dust of glass and mineral fibers	3.0

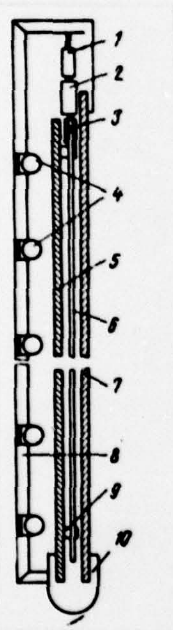

Fig. 9.1. Schematic diagram of pressure gage housing (in section):
1--input of measurable pressure; 2--overflow container; 3--connection with glass pipe; 4--luminescent lamps for illuminating; 5--protective sheet made of plexiglass; 6--pressure gage pipe; 7--anterior protective sheet made of plexiglass; 8--housing frame; 9--attachment of pressure gage pipe; 10--pan for collecting mercury.

In those structures where one can expect accumulation of harmful substances the concentration of these substances in the air is systematically checked, and if the permissible concentration is exceeded the appropriate measures are taken.

9.3. Safety Measures when Using Tanks Operating under Pressure

The units on which the motor is tested, the stationary air tanks designed for supplying the aerodynamic pipes, large-diameter pipes and other tanks very often operate under increased pressures. Vessels operating under pressure are exposed to the danger of explosion, therefore if the tanks operate at pressure

(for nonaggressive and nonexplosive media) over $9.8 \cdot 10^8$ l · Pa (10,000 l· kg force/cm^2), then they are periodically checked. On the external surface of the vessel there is usually a painted indication of its registration number, period of the next check and working pressure.

The units which include elements operating under high pressure are generally located on the first floor and have free approaches to them for examination and repair.

The manufacture of tanks operating under pressure employs only those materials which meet the GOST [State Standard] requirements.

In the thermal vaccum chambers during the start of the engine vapors of fuel can accumulate which may ignite with an explosion. In order to prevent at the same time the explosion of the actual chamber structure it is designed with break out doors.

The service personnel are allowed to enter the thermal vaccum chamber only after it has been determined that there are no harmful gases in it, whereby it is mandatory to observe the buddy system in which one person works inside the chamber while the second is outside watching the work of the first so that he could help him in case of any danger.

9.4. Safety in Working with Lifting and Transporting Mechanisms

All the lifting and transporting work--transfer of the motor, lifting it during setting on the machine or removing it from the machine--is done with special lifting and transporting mechanisms.

Telphers and crane-arms are widely used as lifting devices at the testing stations. These mechanisms operate under difficult conditions and therefore it is necessary to frequently examine and check them (not less than twice a year under load). Load-lifting mechanisms are equipped with limiters for load lifting

and a braking device which permits stopping the load at any height of the lift. All the lifting mechanisms must be equipped with emergency switches to stop them if normal control fails. It is forbidden when working with lifting mechanisms: to lift the load in jerks, to stand under the load, to leave the load in a suspended position, to drag the load up (with tension on the cable at an angle). The motors are transported between shops and within the shop by power trucks or small truck , whereby the motor is fastened on a special sub-motor frame. The most advanced method of transportation is transporting on special carts on which the motor is conveyed directly to the stand. During transporting the workers must accompany the load, to the side or behind it.

9.5. Protection from Debris from the Rotating Parts during Accidents and Special Motor Tests

During accidents of the motor or during special tests (for example, when determining the maximum possible rotation frequency--racing patterns), as well as when testing the motor for impenetrability of the bodies destruction of its rotating parts occurs. Debris from the rotating parts scatters with great kinetic energy. In the practice of testing cases of the turbine disk exploding occur. Debris from the disk, having penetrated the steel body and bent a steel screen 20 mm thick, still possessed sufficient energy to make a hollow 150 mm deep in a concrete wall. In order to prevent the fragments from falling on the people in the observation booth they are protected by a thick ferroconcrete wall. The windows in the observation booth are made of bullet-proof glass (organic or special silicate).

In addition, in order to protect the observation booth windows other armor protection is used made of thick steel sheets (about 40 mm thick)or of thinner sheets of steel with elastic (rubber) layers between them. The schematic diagram

of this armored protection is presented in fig. 9.2.

In a number of cases shields are used which consist of several (three-four) layers of steel mesh (GOST 5336-67) with mesh 15-20 mm. Above the screens are attached on the bracket, their lower sections fastened with a cleat made of angle iron; under the influence of the forces of gravity the cleats of the screen are tightened. Experience shows that the shield made of the screen reliably protect people from debris and make it possible to preserve a good view.

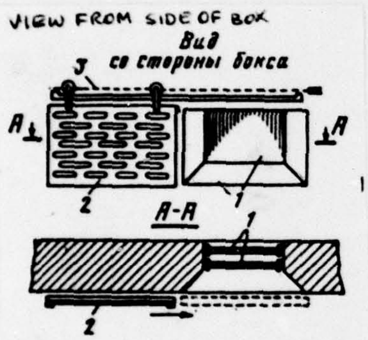

Fig. 9.2. Schematic diagram of armored shield for protecting observation booth windows: 1--armored observation booth; 2--retractable armored shield with slits; 3--cable of mechanism for moving armored shield.

In planning new testing stands it is nevertheless not recommended to place the viewing windows in the plane of rotation of the engine rotor.

9.6. Protection from Effect of Input and Output (Reactive) Gas Stream

The danger zone near the motor for the testing time is fenced off by special guard rails or chains hung on stands. During the operation of the motor people are allowed to enter the room only in a low gas pattern in order to adjust the motor.

The motor air intake is usually protected by a screen (fig. 9.3.) The diameter of the housing on which the screen is stretched must equal two diameters of the input, while its length equals 1.5-2 diameters.

The space into which the combustion products escape is fenced off.

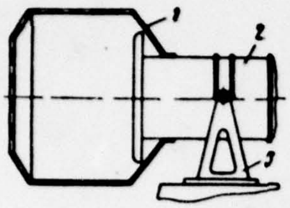

Fig. 9.3. Schematic diagram of protective screen at entrance to motor: 1--screen; 2--motor; 3--elements of testing machine.

9.7. Safety during Servicing of the Motor on the Test Stand

During the use of the motor on the test stand or during its testing the service staff must strictly observe the servicing regulations in which the safe working conditions are defined.

The motor should be mounted on the test stand only by a tool in good working order and in strict sequence. The quality of the performance of each operation is checked by the foreman or the senior mechanic. After the end of the entire set of work a general examination is made of the motor on the test stand during which special attention is given to the fastening of the motor on the machine, the locking of the main units, securing of the gages and their connection to the measuring instruments, sites of connecting the fuel and oil systems to the motor.

An especially attentive check should be made to see that there are no foreign objects in the box which should not be there. The inlet and outlet sections of the motor are usually covered with caps which are removed before starting. So that it is not forgotten to remove the caps they are painted red or red flags are attached to them.

Directly before starting the motor the mechanic is obliged to check the condition of the motor and its fastenings, engage the electrical supply, open the compartments, check the hermetic seal of the fuel and oil systems, the serviceability of the fire-fighting resources, be assured that there are not

foreign objects in the box and that the danger zones are fenced off, check the accuracy of the position of the tumbler switches on the panel and the accuracy of the motor controls.

Usually the order of the examination is regulated by special instructions in which the specific peculiarities of the test stand and motor are considered.

The motor can be started only when there are no people in the box. The process of starting and bringing the motor to the rotation frequency corresponding to the low gas pattern is controlled by instruments.

If gas or fuel leaks are found or if the oil pressure is below the permissible, if a sharp drop is observed in the rotation frequency, a drastic increase in vibrations, a rise in temperature of gas for the turbine above the permissible or other emergency situations occur which are stipulated by the operating manual, then the motor is immediately stopped. Restarting is only allowed after the cause of the defect is found and eliminated.

The service staff must observe the regulations of personal hygiene. The staff is allowed to work only is special work outfits which must be stored in metal lockers set up in the dressing rooms. If synthetic fuels or oils fall on the body surface this area must be carefull washed. After the motor is stopped all circuits are cut off, the tumbler switches are reset on the panel and the test stand feed is disengaged. For a certain time after the stopping of the motor it is not allowed to enter the box in order to avoid poisoning by carbon dioxide and other harmful vapors. After the box has been ventilated the inlet and outlet compartments are closed. Departure from the test stand is permitted only after the motor has cooled completely.

9.8. Fire Prevention in Production Areas

Testing stations and laboratories belong to the category of areas with

increased fire risk. Therefore, during their construction and the set up of equipment, as well as during use a number of measures are taken which prevent the development of fire.

Fireproof materials are used in the construction.

The fuel supply system is generally centralized, the pipes are laid in the ground beyond the structure. At the branching sites of the pipes shafts are made for examining the pipes and their connections. Excess fuel is removed by a drainage system and it is piped to a separate tank. All the pipes of the fuel system are carefully connected by welding or screw joints and they are periodically checked for their hermetic seal.

In case of fire in the area of the station the fuel supply is cut off by an emergency fire valve whose control is on the panel and is duplicated with disengagement of the motor. The actions of the testing team must be assigned in advance and each must clearly know their responsibilities.

Various fire-fighting resources are used to extinguish the fire: sand, felting, carbon dioxide extinguishers which are located in the box in areas which are easily accessible in case of emergency.

A very effective means of extinguishing a fire is inert gas which fills the area; at the same time the fire stops as a consequence of the reduction in content or the lack of oxygen in the area which is necessary for combustion. The fire-fighting system which uses inert gas differs in its rapid action (20-40 s). All the channels which connect the box to the atmosphere must be covered with screens especially designed for this purpose.

The flowsheet for the system of gas fire-extinguishing is given in fig. 9.4. The system includes cylinders 1 filled with pressurized inert gas. In case of fire, upon signal from the temperature-sensitive element the electropneumatic

valves are opened and the gas flows along pipe 3 to the areas especially dangerous during fire.

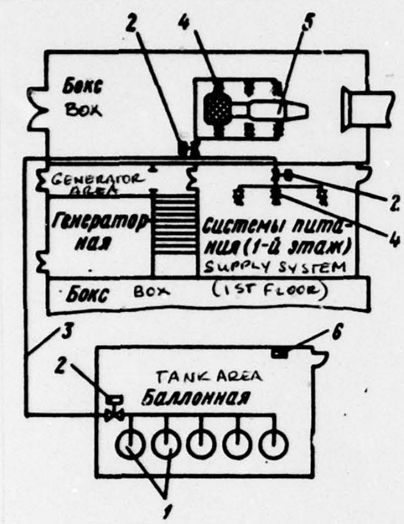

Fig. 9.4. Flowsheet of system for gas fire-extinguishing:
1--tanks with compressed or liquefied gas; 2--electropneumatic valves; 3--pipe; 4--sprayer-mixers; 5--motor; 6--gas analyzer.

Carbon dioxide, nitrogen, composition "3.5" and other gases or special mixtures are used as the inert gas. Despite its high efficacy composition "3.5" is used comparatively rarely since it is toxic and has a destructive effect on a number of materials used in motor construction.

The cause of fire may be an open flame or spark occurring when metal parts strike each other or during the discharge of static electricity. All the possible sources of fire are carefully examined and the possibility of the emergence of fire is eliminated. In order to avoid the accumulation of charges of static electricity all the pipes which carry fuel and oil must be grounded.

As fire prevention measures it is forbidden to smoke on the territory of the testing station outside areas set aside for this purpose, to work with open flames, to weld without special permission, to work with tools not in good working order and to use faulty electric wiring.

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